REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	January 1995	

4. TITLE AND SUBTITLE
Development of Disease and Non-Battle Injury Casualty Rates for the U.S. Air Force

5. FUNDING NUMBERS
PE – 64703F

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8. PERFORMING ORGANIZATION REPORT NUMBER
AL/YA-PC-1994-0023

9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Paper presented at the Society for Computer Simulation 1995, Western Multi-Conference, January 15-18, 1995, Las Vegas, NV; will be subsequently printed in the Proceedings.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

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14. SUBJECT TERMS	15. NUMBER OF PAGES	16. PRICE CODE
	6	

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unclassfied

DEVELOPMENT OF DISEASE AND NON-BATTLE INJURY CASUALTY RATES FOR THE U. S. AIR FORCE

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ABSTRACT

This paper presents the deliberations and conclusions of a series of U.S. Air Force (USAF) expert panels convened to derive a methodology and supporting data for predicting the likely number of disease, non-battle injury and battle reaction (DNBI) casualties to be expected among USAF personnel during future wartime operations. The information supports development of the Threat Related Attrition (THREAT) System, a model for estimating casualties from conventional and conventional warfare.

INTRODUCTION

Accurate casualty estimates are essential to effectively plan replacements and the type and amount of medical resources required during conflict. The Human Systems Program Office has been tasked to develop the Threat Related Attrition (THREAT) System (Wilson 1992). The THREAT System will estimate casualties for a spectrum of threats and conflict intensities. The system is composed of models which allow estimation of attrition rates (number per 1000 population at risk per day) at different levels of aggregation. These models are the Casualty Generation Model and the Facility Model. The former contains the DNBI module. This paper summarizes a succession of developmental activities leading to the accomplishment of the DNBI module in the CGM (Whitehead *et al.* 1991; Stika and Goldman 1992; Sharon and Shephard 1993)

Diseases and non-battle injuries have historically been a greater source of casualties than battle injuries (Beebe and DeBakey 1952; Lada and Reister 1975; Reister 1986). In some conflicts, the ratio of disease to injury cases was as high as 10:1. The incidence of psychological reaction to combat can also be substantial. For the 1982 conflict in Lebanon, Israeli forces suffered a ratio of 23 psychiatric casualties for every 100 wounded-in-action (WIA) casualties (Belenky *et al.* 1985). Improvements in field hygiene and preventive medicine have lowered the incidence of DNBI, as illustrated by Operation Desert Storm (Hanson 1991; Shaw *et al.* 1991). However, it is still a primary contributor to personnel attrition and medical workload. Also, the ratio to battle injury should remain high as new war fighting tactics are employed, which will lower the number of WIA casualties. Therefore, it is necessary that any casualty estimation model account for DNBI and psychological reaction to combat as significant sources of attrition.

APPROACH

The Methodology Panel, composed of USAF medical and epidemiology experts, convened to approve and comment on the proposed procedures for modeling DNBI and stress casualties. The panel results follow.

Several approaches were considered. Many of these alternatives involved DNBI studies that were ongoing or recently completed by the various military branches. In addition to the approaches used by the other services, a cause and effect, multiple disease modeling approach was considered. The advantages and disadvantages of these alternatives were discussed with consideration given to accuracy, data availability, complexity of implementation, relevancy to USAF operations, and allowable developmental cost and schedule. The recommended methodology was to produce a Service-unique statistical approach that would attempt to capture the complex relationships between the numerous variables.

A preliminary literature search yielding over 180 references was supplemented by interviews with experts in the field. A summary of this data were presented to the panel. Many of the sources of data on DNBI casualties were found to be insufficient for the purposes in hand; typically they were non-uniform in presentation (for example, in classifying diseases and casualties), tended to be out-of-date, could not be related to the relevant population at risk (PAR), referred to services other than the USAF, and did not cover the many locations of interest. Therefore, the panel decided it necessary to

develop an original baseline database tailored to the task in hand.

However, available data sources for USAF personnel contained only peacetime data and excluded some locations -- Africa, South America, and Southwest Asia. It was, therefore, proposed to use a number of expert panels, composed of experienced USAF medical officers and using a modified Delphi technique, to make the necessary extrapolations to redress these deficiencies. Another expert panel, composed of psychiatrists and psychologists, would be used to develop a method for estimating the number of casualties caused by stress as a direct result of exposure to enemy action.

Before detailing the terms of reference and the procedures employed in the paneling, it is important first to set out two over-riding conditions that the Methodology Panel ruled should be applied to all deliberations.

It would be assumed that the relative mix by race, age, and sex within the USAF will remain relatively constant in the near future. Any influences these demographic factors may have are embedded within the occurrence data. Thus the effect of these variables on the DNBI rate need not be analyzed.

Because it is impossible to predict the precise time of year in which a future operation would take place, an average annual rate is adequate for planning purposes.

The four panels, together with their terms of reference, were as follows:

Baseline Panel To produce a set of standard rates for serious and slight DNBI casualties in peacetime as a function of location and Air Force Specialty Code (AFSC) identifiers.

War vs. Peace Panel To produce a series of multipliers that will enable the Baseline Panel's peacetime rates to be converted to wartime rates.

Battle Reaction Stress Panel To reproduce the work of the other panels, but for casualties due to mental disorders. Additionally, to develop a method of estimating the number of battle reaction casualties to be expected as a direct result of exposure to enemy action.

BASELINE RATES

Definitions

Two terms must be defined before proceeding. For the purpose of our modeling, casualties are described as being "serious" or "slight" according to the treatment they need and where this is to take place. Specifically, "serious" in the present context is taken to mean admitted for treatment. A "slight" casualty defines a casualty returned to duty (RTD) without requiring admission. Normally the RTD will be within 24 hours including, on occasions, a short convalescence in quarters.

Serious Casualties

In the records used, serious DNBI casualties were classified according to the International Classification of Diseases, 9th Revision (ICD-9). In this source, diseases and injuries were divided into 17 Major Categories

The panel excluded Major Categories 14 and 15 from the list of DNBI casualties for which rates were to be given. Serious congenital anomalies would be discovered during medical examinations at the time personnel applied to join the USAF, and would result in their not being recruited; if these conditions were diagnosed subsequently, it would only be incidental to other diagnoses. Perinatal conditions would not be found in an active theater of operations because of deployment policies.

The Methodology Panel recommended that the first Major ICD-9 Category, Infections and Parasitic Diseases, be divided into five subcategories, paralleling some the later ICD-9 major categories. The net result was to leave 19 categories distinguishable in the database (Table 1).

TABLE 1. CATEGORIES OF SERIOUS DNBI CASUALTIES

Category	Designation
1A	Infectious and Parasitic Diseases:Gastrointestinal
1B	Infectious and Parasitic Diseases:Respiratory
1C	Infectious and Parasitic Diseases:Genitourinary
1D	Infectious and Parasitic Diseases:Dermatological
1E	Infectious and Parasitic Diseases:Febrile
2	Neoplasms
3	Endocrine, Nutritional and Metabolic Diseases, and Immunity Disorders
4	Diseases of the Blood and Blood-Forming Organs
5	Mental Disorders
6	Diseases of the Nervous System and Sense Organs
7	Diseases of the Circulatory System
8	Diseases of the Respiratory System

9	Diseases of the Digestive System
10	Diseases of the Genitourinary System
11	Complications of Pregnancy, Childbirth, and the Puerperium
12	Diseases of the Skin and Subcutaneous Tissue
13	Diseases of the Musculoskeletal System and Connective Tissue
16	Symptoms, Signs, and Ill-defined Conditions
17	Injury and Poisoning

A database for serious DNBI casualties for 1981 through 1985 was derived from incidence data obtained from the Air Force Medical Support Agency (AFMSA) supplemented by population at risk data from the USAF Military Personnel Center. Over 600,000 DNBI casualties among active duty personnel in peacetime were enumerated for 117 USAF bases and distinguished by occupational groups. The numbers of personnel at risk were mapped to this data enabling DNBI rates to be calculated based on primary diagnoses.

A number of analyses of these data were made at the behest of the panel. The panel concluded from these that it is not possible to discern any operationally significant differences in overall DNBI rate with geographical region, climatic zone, population density, or Physical Quality of Life Index. Nevertheless, because there was some evidence that the balance of the contributions from different ICD-9 Major Categories varies from climate to climate, the panel quoted a baseline (peacetime) rate for three separate world regions (US, Pacific, and Europe) as well as for all theaters together.

There was, however, a significant difference in DNBI serious rates between officer and enlisted men, and between occupational groups within these categories. Because of their utility for planning purposes, fourteen occupational groups were adopted for grouping AFSCs. Table 2 reveals the overall rates for all locations and occupational categories for each major ICD-9 category.

TABLE 2 OVERALL SERIOUS DNBI RATES BY MAJOR ICD-9 CATEGORY (#/1000/DAY)

Overall	1A	1B	1C	1D	1E	2
0.726	0.042	0.008	0.001	0.004	0.077	0.005
3	**4**	**5**	**6**	**7**	**8**	**9**
0.005	0.001	0.025	0.018	0.013	0.118	0.166
10	**11**	**12**	**13**	**16**	**17**	
0.034	0.015	0.018	0.069	0.025	0.080	

Slight Casualties

The original intent was to allocate ICD-9 code descriptions to slight DNBI casualties in the same manner as to the serious DNBI casualties discussed above. It soon became apparent that this procedure was not practical because of a lack of data.

A new scheme in which slight casualties are divided into 11 categories was therefore derived, based on panel members' expert knowledge, considerations of data availability, and compatibility with other category schema.

One DNBI slight rate was quoted for all locations and all AFSC groupings. On the basis of limited data from Desert Shield/Storm and a number of large scale exercises, the panel recommended an overall rate of 18 per thousand at risk per day as a baseline rate. Deliberations about the manner in which this should be divided among the 11 categories are given in Table 3.

TABLE 3. BASELINE SLIGHT DNBI RATES

Category	Designation	Proportion of Total Rate	#/1000/ Day
A	Respiratory	24%	4.3
B	Gastrointestinal	10%	1.8
C	Dermatological conditions	10%	1.8
D	Non-battle injuries (NBI)	18%	3.2
E	Sexually transmitted diseases	2%	0.4
F	Psychiatric conditions	14%	2.5
G	Minor medical	10%	1.8
H	Minor surgical	6%	1.1
I	Climatic	2%	0.4
J	Eye	2%	0.4
K	Fever	2%	0.4
	TOTAL	100%	18.1

PEACE-TO-WAR MULTIPLIERS

To convert baseline (peacetime) DNBI rates to the rates to be expected in wartime, a series of multipliers was needed. For context, the War vs. Peace Panel envisaged a scenario in which there were few troops in the theater initially. Deployment started on C-day and build-up was rapid, being completed by C+10. Air superiority was established within a few days, and only conventional weapons were used.

The main assumptions agreed about multipliers for serious rates were that the values of the multiplier are

independent of location class and occupational group, but, for some ICD-9 Major Categories, depend upon time after C-day. The final agreed list of multipliers gives values for the periods C-day through C+89 and C+90 through C+179 (Table 4).

TABLE 4. CONSOLIDATED LIST OF MULTIPLIERS FOR SERIOUS DNBI CASUALTIES

Location	1A	1B	1C	1D
U.S.	1.0	1.0	1.0	1.0
Others	11.7 4.0	4.0	2.0	1.6
	1E	2	3	4
U.S	1.0	1.0	1.0	1.0
Others	5.0	1.0	1.0	1.0
	5	6	7	8
U.S	2.0 1.5	1.0	1.0	1.0
Others	2.0 1.5	1.0	1.0	4.0
	9	10	11	12
U.S.	1.0	1.0	1.0	1.0
Others	1.8	1.0	1.0	2.1
	13	16	17	
U.S	1.0	1.0	1.0	
Others	2.5	1.9	3.0	

Note: The upper value applies to C-Day to C+89; the lower value to C+90 to C+179.

Little evidence was available on which to base estimates of the values of multipliers for slight rates. Bearing in mind that the baseline rates were based on information from Desert Shield/Storm and major exercises, the panels considered that these data already include an element which made them somewhat equivalent to wartime conditions. It was proposed therefore that multipliers for all the 11 slight categories should be assumed to have a value of unity for all locations and all occupations.

STRESS CASUALTIES

The Battle Reaction Stress Panel recommended that the number of psychiatric casualties caused as a result of exposure to enemy action be calculated as directly proportional to the number of wounded (serious plus slight) caused by the action. On this basis, the number of combat stress (CS) casualties would be given by an expression:

(# of CS casualties) = α (# of WIA, serious & slight)

where the constant of proportionality, α, depended the manner in which the attacks take place. Two options were considered, representing what are considered extremes of the attacks facing USAF personnel in the general scenario envisaged. These are referred to as High Intensity, short term and Low Intensity, long term. Typical of the first of these would be a series of attacks on an installation of 5000 personnel causing approximately 100 wounded in action (WIA) each day over 10 days. The Low Intensity option would typically consist of light attacks, causing perhaps 10 WIA per day or less over several months.

For the High Intensity option it was estimated that there would be a number of battle reaction casualties equal to 36% of the number WIA (Stokes *et al.* 1988). These would be spread over three days, 60% of them occurring on the day of the attack, 25% on the next day, and 15% on the third. For the Low Intensity option, battle reaction casualties are estimated at 18% of the number WIA. This is a daily rate. The severity of the casualties for each of these two scenarios was also allocated by severity of the attack environment. The panel estimated that 76% of battle reaction stress casualties due to a High Intensity attack are expected to return to duty without being evacuated: For the Low Intensity attack, the figure rises to 91%.

VERIFICATION

As the DNBI module is a statistical model, it is heavily data dependent. Therefore, the majority of the verification effort focused on verifying the data supporting the model (Wilson *et al.* 1993). There were three areas of focus.

Population Demographic Analysis

The DNBI modeling methodology is based on the assumptions that the population demographics of the population at risk will remain constant, and that the population used to produce the rates represents the population for which casualty predictions will be made. These assumptions were examined.

A phased approach was adopted. The first examined historical trends and the second considered the sensitivity of the serious DNBI rates to changes in these factors. The first phase was intended to provide a feel for the volatility of these factors over recent years. Although the continued volatility of past changes into the future is not guaranteed, it was felt that the trend would give some feel for their expected magnitude. The second phase assessed the

importance of future changes in USAF demographics whether they change or not. If it were found that the serious DNBI rate is insensitive to these demographic factors, the validity of the assumption would be of no consequence.

There was a slight positive trend in the proportion of females in the USAF over the 1981 to 1989 time period. The slope of the trend line was small, approximately one-third percentage point per year. With the pending decrease in the total force size over the next few years it was not clear whether this trend would continue. Regardless, it was necessary to determine the significance of the trend as it affects the estimated serious DNBI rates before an assessment of the appropriateness of the demographic assumption can be made. No apparent trend existed for the other two factors of race and age.

The values of the correlation coefficient between the DNBI rate and each of the demographic factors were all extremely low indicating there is not a linear relationship between them. The low multiple R value resulting from the multivariate regression analysis and the high probability that the regression coefficients could be zero supported this observation.

Unfortunately, these statistical tests examined linear relationships between the variables and did not ensure the variables were not related in some non-linear fashion. Scatter plots did not indicate any reasonable non-linear relationship between the value of the demographic variables and the serious DNBI rate. It was clear that knowledge of the value of a demographic variable did not provide any information about the corresponding rate.

Dead on Arrival Analysis

A concern was raised concerning the impact of DNBI casualties which are Dead On Arrival (DOA) at the medical facility on the DNBI rate. It was reasonable to assume that these should be included in the total DNBI rate, but they were not included in the AFMSA admissions data.

The average DOA rate for the Air Force during the period 1981 through 1985 of 0.002 is extremely small in comparison to the total DNBI rate during the same period of 0.726. Given the magnitude of the DOA rate and the expert opinion exercised during the panel sessions, further refining of the DNBI rate developed by the panel to account for DOA incidents was not warranted.

Slight DNBI Rate Analysis

The intent of this analysis was to evaluate the methodology used in determining the slight DNBI rates and to validate the rates using independently derived medical data newly obtained from the U.S.Navy (USN). The USN data consisted of a number of months of Medical Services and Outpatient Morbidity reports from a number of ships over a period of time.

The percentages of total visits by category for the USN slight DNBI data agreed closely with those estimated by the USAF panels with two exceptions (Table 5). The occurrence of psychiatric cases appeared to be notably lower than the USAF panels' prediction while minor medical cases occur at a rate higher than predicted by the panels. There were possible explanations for these differences; however, their validation was beyond the scope of this effort.

TABLE 5. PROPORTION OF TOTAL VISITS BY SLIGHT CATEGORY

Category	Designation	USN %	USAF %
A	Respiratory	29	24
B	Gastrointestinal	9	10
C	Dermatological conditions	14	10
D	Non-battle injuries (NBI)	19	18
E	Sexually transmitted diseases	3	2
F	Psychiatric conditions	1	14
G	Minor medical	20	10
H	Minor surgical	4	6
I	Climatic	1	2
J	Eye	1	2
K	Fever	0	2
	TOTAL	100	100

The slight DNBI rates obtained from the USN data were independent of the size of the ship, population at risk, and the ship environment -- at sea or in port. Therefore, the data could be used without regard to the size of the ship's company or environment for comparison with the USAF derived rates.

Comparisons with the USN slight DNBI data and discussions with a USAF panel participant indicated the THREAT System slight DNBI rate estimates were based upon total medical system workload, which includes initial visits and revisits. The 95% confidence interval for the total visit rate derived from the USN data was 0.60 - 20.96. The USAF panel-derived value for the total slight visit rate of 18 per thousand per day was within this

interval. This fact would tend to substantiate the USAF panels' estimate of total slight workload on the medical system to include both initial visits and revisits. The 95% confidence interval for an initial visit rate derived from the USN data was 1.46 - 14.56. Subsequent analysis of additional USAF data from Operation Desert Storm led to a recommended USAF slight initial visit rate of 13 per thousand per day, which is within this interval.

CONCLUSION

The data and methodology described above are now being incorporated into the Casualty Generation Model of the THREAT System. The first version of the integrated system will be available in 1995. The DNBI rates as derived will be applied against PAR data input at the time of the simulation. Wartime multipliers will be accepted as given or altered to concur with the conditions underwhich the scenario is derived. When and if future operations occur, we will be able to validate the estimates made by the THREAT System.

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